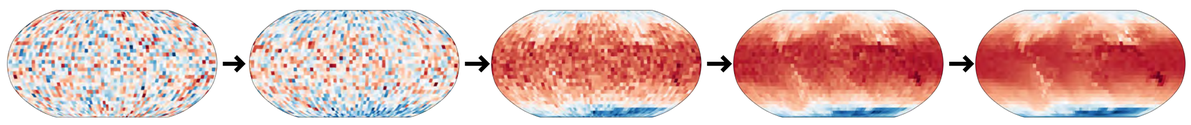
Continuous Ensemble Weather Forecasting with Diffusion Models

Martin Andrae[1] Tomas Landelius[2] Joel Oskarsson[1] Fredrik Lindsten[1]

[1]Division of Statistics and Machine Learning, Linköping University [2] Swedish Meteorological and Hydrological Institute

Ensemble Forecasting with Diffusion models

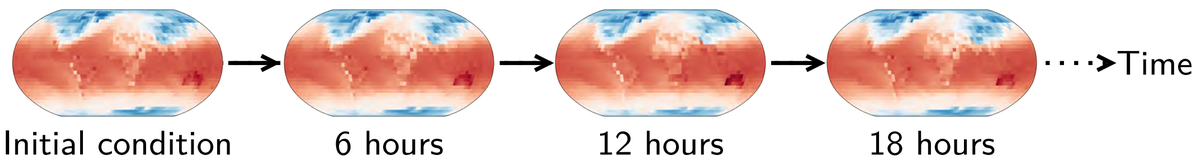
Conditional Diffusion models have demonstrated success in ensemble weather forecasting with GenCast.



The diffusion process is conditioned on the initial condition. Each noise sample gives one forecast (ensemble member).

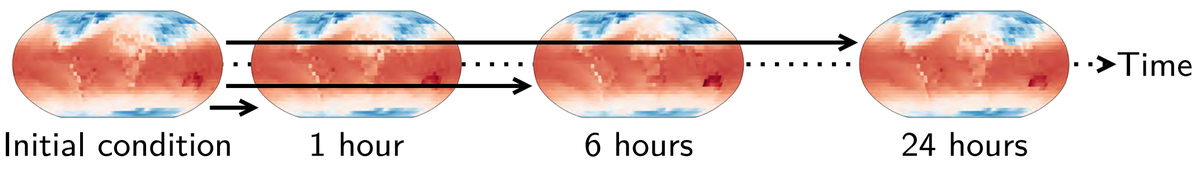
Current approaches to forecasting

Autoregressive Forecasting (AR) train a model with a fixed time step and applies it iteratively up to the forecast horizon.



This is effective with long (24h) steps but accumlates errors when used with fine (1h) time resolution.

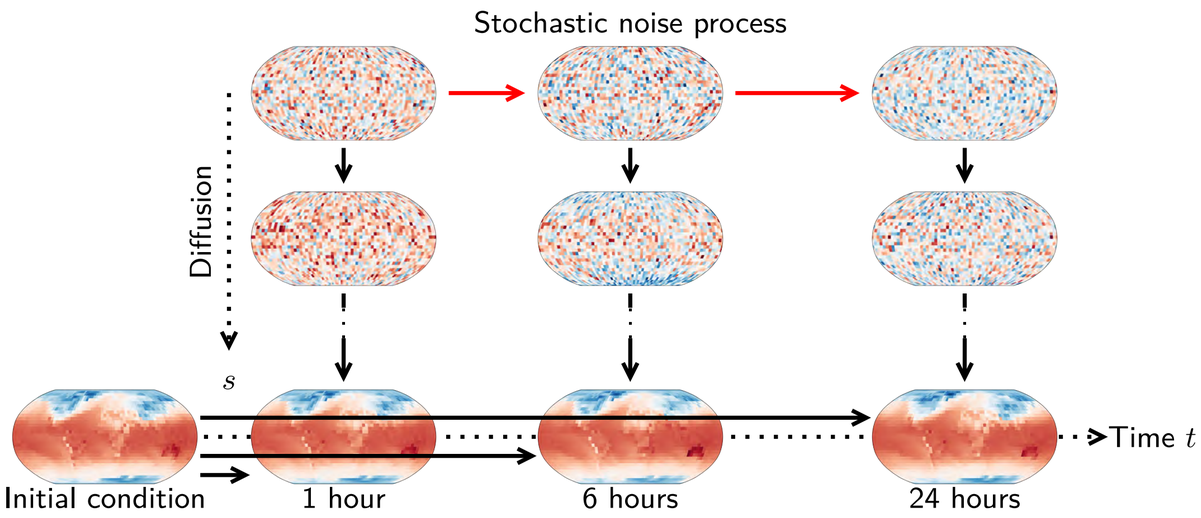
Continuous Forecasting train a model with a variable time step and produce forecasts directly from the initial condition.



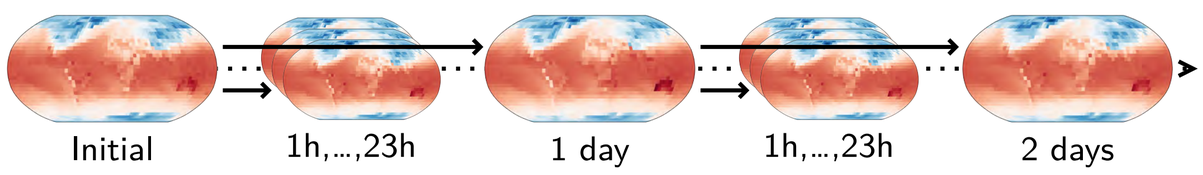
This produces forecasts at any time resolution but cannot give you the forecast trajectories.

Continuous Ensemble Forecasting

Our method, **Continuous Ensemble Forecasting**, uses a conditional diffusion model to do continuous forecasting. To ensure temporal consistency, we correlate the driving noises for the different lead times.



As t increases, continuous forecasting becomes much harder. To generate longer forecasts we propose **Autoregressive Rollouts with Continuous Interpolation (ARCI)**.



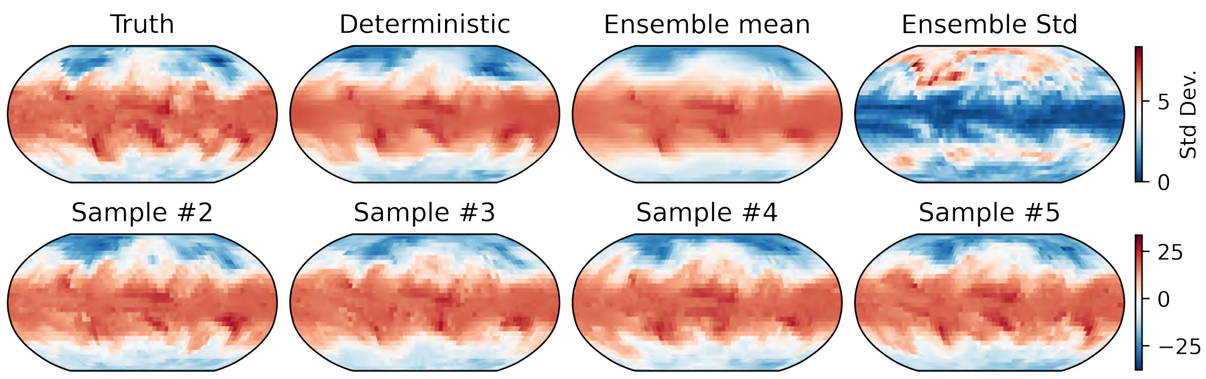


Figure 1: Forecasts of temperature at 850 hPa (t850) at 10 days

Results on Global Weather Forecasting

- We use a standard U-Net with 3.5M parameters.
- Trained on 5.625° ERA5 reanalysis data from 1979-2015.
- Variables `z500`, `t850`, `t2m`, `u10`, `v10` at 1h resolution.

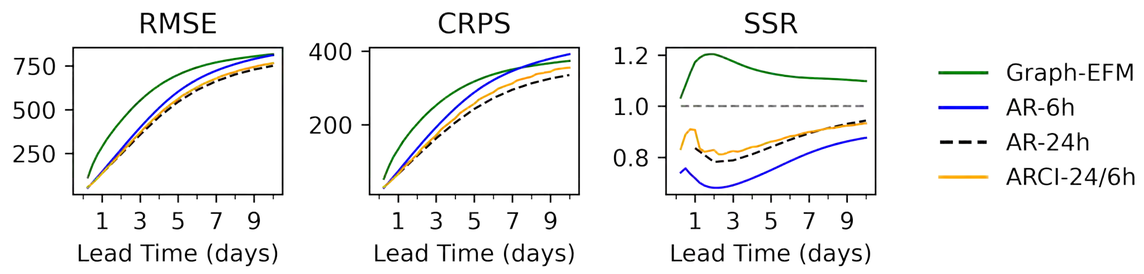


Figure 2: Results for 6h forecasting (z500) with 50 members

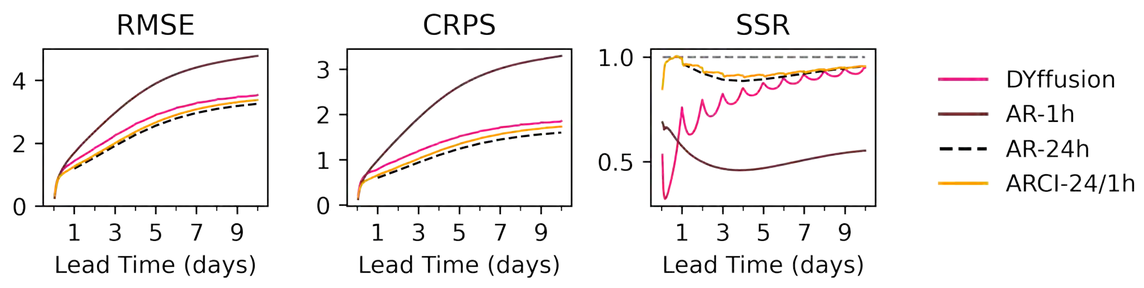


Figure 3: Results for 1h forecasting (t850) with 10 members

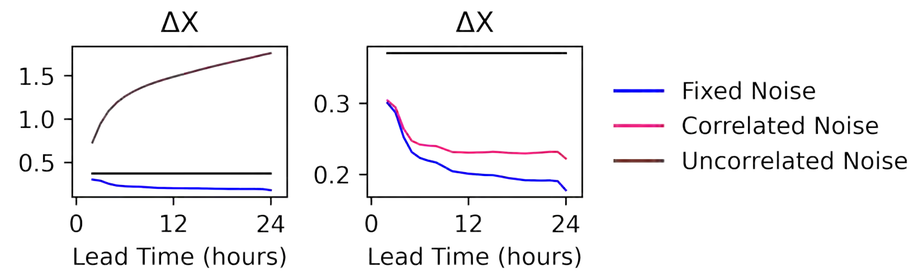


Figure 4: Temporal difference (t850) for type of noise process

Key takeaways

- ARCI can generate 10-day forecasts at a high temporal resolution (1h) without degrading its performance.
- ARCI outperforms other probabilistic models such as GenCast (AR-6h), DYffusion and Graph-EFM.

Links

Website

Scan QR-code for link to website with paper, code, and animations.

Correspondence to:
`martin.andrae@liu.se`

LINKÖPING UNIVERSITY

WASP WALLENBERG AI, AUTONOMOUS SYSTEMS AND SOFTWARE PROGRAM